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ABSTRACT

Preliminary evidence indicates that children begin to generalize knowledge in a new way at approximately 3 years of age. Forty children between 1.5 and 3.5 years of age were given two tasks of graded complexity. The first and simpler task used four nonoverlapping classes, each composed of four identical objects. Two of the classes were tagged with stickers hidden underneath. The second task used four crossed classes, each composed of four objects plus a fifth "unrelated" class. In this task, stickers were attached to two disjunctive classes. In both tasks, children were asked to determine which objects had stickers. The major finding was that, as age increased, the frequency of children's selection and organization of untagged objects also increased. In the process of establishing a particular category, subjects appeared to test the limits of that category by examining instances they believed did and did not belong. Younger children examined only additional likely instances of a specific category. This developmental process appeared to occur in children's reasoning about reality and in their acquisition of grammar. Although when very young children were confronted with a novel event, they compared it with something familiar, by age 3 or so they examined how their analogies didn't work and drew out implications of what they hadn't seen. (Author/RH)

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THE DEVELOPMENT OF INDUCTIVE STRATEGY IN CHILDREN'S EARLY THOUGHT AND LANGUAGE

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THE DEVELOPMENT OF INDUCTIVE STRATEGY IN CHILDREN'S EARLY THOUGHT

One may test a generalization by examining likely supporting instances of it or by examining likely negative instances, to eliminate alternative generalizations. Very young children appear to use the former method, alone, and then develop the latter method.

Forty children between 1½ and 3½ years of age were given a simple categorization problem. At around age 3, the children began to search for negative instances of concepts they were in the process of forming. They were proceeding by a process of elimination. That is, in the process of establishing some category, A, they appeared to test the limits of A by examining instances they believed both were and were not members of A. The younger children examined only additional likely instances of A.

Verbal reasoning at the same ages has similar features. When young children are confronted with a novel event, they compare it with something familiar, to make sense of it. But by 3 or so they do more than simply analogize. They examine how their analogies don't work, and they draw out the implications of what they haven't seen. Despite other evidence that children and adults are disinclined to use "negative" instances to form concepts, consideration of what something is not (or of what instances are not members of A) may be a major means by which children determine what is.

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THE DEVELOPMENT OF INDUCTIVE STRATEGY IN CHILDREN'S EARLY THOUGHT AND LANGUAGE

One basic component of both scientific and everyday thinking is to generalize from what is known about one thing to what is true of some previously unexamined group of things. This is how children construct their reality, a reality that includes physical, social, and linguistic objects.

We have preliminary evidence from a study involving children's manipulation of physical objects that children begin to generalize their knowledge in a new way at around 3 years of age. Today I will present these results. I will then discuss possible extensions of the findings to children's language learning and to their spontaneous "unpacking" of other realities.

A Preliminary Finding

We gave 40 children between 1½ and 3½ years of age two tasks of graded complexity. In each task the children were to determine which objects from a large array had a sticker hidden underneath. The first, and simpler (Nonoverlapping), task used four nonoverlapping classes of four identical objects each: discs, squares, columns, and trees, with each class a different color. Stickers depicting apples were attached to the bottoms of all the discs and squares. The second (Overlapping) task used four crossed classes of four objects each: green brushes, yellow brushes, green triangles, yellow triangles. A fifth "unrelated" class of blue columns was

added to these. Stickers depicting cats were attached to two disjunctive classes, the green brushes and yellow triangles (see Figure 1).

Each set of objects was presented in a scrambled array, one exemplar from each tagged class was turned up, and the child was told to find "the other apples/kitties". Tasks were terminated after three minutes or when the children signalled that they would search no further.

The children made an average of 20 discrete selections in the Nonoverlapping task, and 21 in the Overlapping task. Selection frequency did not vary with age in the Nonoverlapping task, but increased with age in the Overlapping task ($p < .03$). It did not correlate with our dependent measures in either task, however, and thus should not have produced age-related artifacts on these measures.

The major finding is that as the children got older they selected and organized the untagged objects with increasing frequency:

1. In each task, the proportion of selections involving untagged, as opposed to tagged, objects increased from one-fourth at 18 months to fully half at 42 months. The heavy line in Figures 2A and 2B shows this trend.

2. Again in both tasks, there was a reversal with age in the conditions under which the children sequentially selected identical objects. In each task, the 1½- to 2½-year-olds were more likely to choose an identical object if they had just chosen a tagged object than if they had just chosen an untagged object. By 3½, however, the children were more likely to choose an identical object after selecting an untagged object than after selecting a tagged object. These results are graphed in Figures 3A and 3B.

Our secondary finding has to do with differences among the younger groups, the children who were selecting mainly tagged items. As it turns out, the very youngest children were not only selecting and classifying tagged objects, but were selecting and classifying only one of the two classes of these objects:

1. Figures 2A and 2B show that in each task the 18-month-olds selected one of the two tagged classes twice as often as they selected the other: discs were favored in the Nonoverlapping task, and brushes in the Overlapping task. By 30 or 36 months, the children selected from the two tagged classes equally often.
2. Figures 4A and 4B show that until 30 months the children were more likely to select an identical object after having selected an object from their more frequently used tagged class than they were after having selected an object from the other tagged class. So, in the Nonoverlapping task, these younger children were more likely to select an identical object after having selected a disc than after having selected a square. In the Overlapping task they were more likely to select an identical object after having selected a (green) brush than after having selected a (yellow) triangle. The older children did not show this discrepancy: they were as likely to select an identical object after having selected an object from one tagged class as they were from the other.

The data thus contain two trends. One is from the selection and classification of one class of tagged objects to the selection and classification of two classes of tagged objects. The other is from the selection and classification of tagged objects to the selection and classification of both tagged and untagged objects.

We need a control analysis before we can interpret these trends. The children did not check the bottom of every object they chose. Roughly half the moves at every age consisted of displacements without checking. Accordingly, we reanalyzed the data using checked moves only, on the assumption that maneuvers following these moves were more likely than maneuvers following unchecked moves to be related to subjects' notions about where the stickers were. This analysis strongly confirms the initial one, in two ways. First, the two developmental trends I have described were replicated for checked moves only. The only difference is that children at every age checked tagged objects more often than untagged objects. Thus, for example, the oldest children checked the untagged objects more often than the younger children did, as before, though they checked more tagged than untagged objects (they selected equal numbers of each). Second, and more impressively, the interaction we found for identical-object selections following tagged vs. untagged selections was accentuated when we considered only checked moves. When the oldest children had checked an untagged object, they were extremely likely (that is, after an average of 80-90% of these moves) to select an identical object next. When the younger children happened to check an untagged object, they rarely went on to select another object from the same class (they did so on no more than a third of these moves).

The behavior of the younger children seems reasonable. They sought out those things that, on the basis of the evidence they were given, were likely to have stickers. The 1½-year-olds used just one criterion (one class) to do this, while by 2½, the children selected objects by two criteria. This trend is consistent with our earlier results on free classification (Sugarman, 1982).

However, the youngest children not only sought one class, they all sought the same class. This group bias toward one particular class of tagged items suggests that something was especially salient to these children about these objects, other than the stickers. This feature, in turn, helped the children distinguish these objects from the rest of the array. That is, to the extent that they were looking for something like an element they knew to have a sticker, that element was not hard to find. This finding, too, converges with earlier results: Object grouping seems to be associated initially with the decided salience of one class over the other available objects (Starkey, 1981; Sugarman, 1981).

But why should the oldest children both sample and classify the untagged objects, especially after having ascertained that these objects were in fact untagged? At least in the Overlapping task, they were proceeding by a process of elimination. If a green brush had a sticker showing, for example, they would check a yellow brush. Finding no sticker on it they would remove all the yellow brushes from the array and then (or at some later point) turn up all the green brushes. They would then subdivide the green and yellow triangles the same way, perhaps checking some blue columns along the way:

> TU, 42 months. T checked a yellow brush (no sticker) and then a green brush (sticker). She moved all four yellow brushes to the left of the array: "OK, all these have to line up." She checked a yellow triangle (sticker) and then a green one (no sticker). She lined up three green triangles (no stickers) to the left: "All these..." She turned over the last two yellow triangles (stickers): "This have...there it is." She checked one blue column (no sticker) and then moved three of them, without checking, to the left. She checked the last yellow brush (no sticker) and left it in place. Then, with very deliberate motions, she turned over the remaining green brushes, displaying the stickers on them.

In this task, then, it appears that the oldest children were selecting untagged objects primarily because they were sorting among closely related items to find the ones that had stickers. But they also checked less related untagged objects: the blue columns in the Overlapping task, and the untagged objects (columns and trees) in the Nonoverlapping task:

> TU, 42 months (Nonoverlapping task). T turned up a disc and a square, revealing the sticker on each one: "-- two, three." She turned up another disc, and grouped it with the other three discs: "Now one more of these" (by this point she had three discs and three squares upturned, and had grouped all four discs). She turned over a tree: "And maybe try one of these." She checked a second tree and then put three trees together, although she had checked only two of them: "I think we should get rid of these. No smiling faces. (the apples had faces on them)." (emphasis added). She turned over two columns and grouped them: "No." She turned over the fourth square, which had a sticker: "These." She put a third column with the column group, again without checking. Lastly, she turned over the fourth column and put it with the other columns: "Not even these."

The children had in fact received no positive indication that the objects that were unlike the upturned exemplars did not have stickers. It was reasonable for them to check -- and eliminate -- these objects, as well as the untagged objects that were more similar to the tagged items.

Note, however, that the (oldest) children treated these near and distant untagged objects differentially: They checked the distant (less related) objects less often than they checked the near ones (though they still checked objects of both types more often than did the younger children). Moreover, when they did check the distant items, they did so nearly always after they had finished checking the tagged objects. They checked the near, or "overlapping", untagged objects right from the start, that is, during their search of the tagged objects. We have suggested that in inspecting the near untagged objects, the children were trying to discover where the stickers were. In inspecting the distant untagged

objects, they may have been attempting rather to verify their hypotheses.

In any event, the younger children differed sharply from the older children in the way they treated untagged objects of either variety. They did in fact check some untagged objects, especially those that overlapped with the tagged objects. This can be seen in Figure 2B: as early as 18 months children were selecting the untagged objects (in this case the yellow brushes) that were the same form as their favored tagged class. But until 3 or 3½ years of age, the children simply eliminated these bad objects when they encountered them. Having chosen an untagged object, they did not choose another one like it, but went on to choose something else instead. The older children, by contrast, eliminated bad classes. Having chosen an untagged object, they retrieved the others like it and quite literally got them out of the way.

We may note in passing that the 3½-year-olds' behavior is much like that of eight adults we tested on the same tasks. All eight adults checked at least one untagged object in the Overlapping task, and all but one did so in the Nonoverlapping task. Within this context, they gave precedence to the tagged objects, as did the 3½-year-olds. Most of the adults checked all the tagged objects before checking any untagged objects. They also distinguished among untagged objects that were more or less related to the tagged objects. They checked more of the related ones. And, on the rare occasion when they did check an untagged object early in the task, they always checked an object that was more, rather than less, related to the tagged objects. (N.B. In the Nonoverlapping task, there was a greater tendency among adults and children alike to check columns than trees, among the untagged items. The columns were closer in size to the tagged objects than were the trees.) Finally, like the 3½-year-olds, but not the younger

children, the adults were more likely to handle untagged than tagged objects in class order. As with the children, this may have been tied to the eliminative function these maneuvers served. Since the untagged objects were unmarked, there was no way to remember which ones they were, save to use their physical identity to get from one to the other.

The import of the adult patterns, along with the developmental trend toward this behavior is this: A subject who samples both tagged and untagged classes need not be someone who has no idea where the stickers are, but could be someone with a very good idea, who is also aware of other possibilities.

To summarize, our preliminary findings suggest that by 3½ years of age, children may begin to consider what things are not-A as they try to establish what things are A. Younger children consider only additional likely instances of A. For them, an encounter with an instance of not-A, when it occurs, is an "error". For 3½-year-olds and adults, it becomes an elaboration of the search for A.

Possible Extensions to Spontaneous Discovery Procedures

There is no explicit discussion of a development of this type in the literature covering the period from 1 to 4. Analyses of children's syntax are a possible exception, and I will discuss them shortly. Otherwise, the tendency of adults and older children to better appreciate positive than negative instances in concept formation is well documented (e.g., Bruner, Goodnow, & Austin, 1956). It makes sense, then, that the children in our study began to examine things that were unlike the initially marked "positive" exemplars only after a period during which they checked only like items.

But what we really need is evidence that a strategy of the sort I have described does emerge in children's navigations about the world at around the time we have observed it: between 3 and 4 years of age. In the remaining time I will argue that there is such evidence in children's spontaneous analyses of language and other realities. I will argue further that children would be unable to construct these realities -- specifically, to converge with the conventional wisdom on them -- without something like the process we seem to have tapped here.

I draw my account principally from Kornei Chukovsky's (1968) miraculous book, From 2 to 5, which contains children's spontaneous comments about language and other things. It seems to me that the volume is replete with examples of children's concern with 'what is not but could have been', as they try to figure out what is.

To begin with, Chukovsky notes, as have others, preschoolers' compulsion to connect everything with everything else:

> "So much confusing and fragmentary knowledge is heaped upon the young child that if he did not have the fortunate desire to resolve this chaos he would surely lose his mind by the age of 5. Necessity compels him to conduct a tireless classification of all phenomena." (p. 104)

And so, in scrutinizing language and other "facts", children draw out the implication of one utterance or event by analogy to a past, related one. From language: a child hears that somebody's "dog is trained", and sometime later, that someone's father is well trained. The child then asks whether this father is a dog. From the world of events: a child who sees a train kill a pig sees a new pig a few days later and reasons that "the pig glued herself up again". Or, a child sees her grandmother remove her artificial teeth and says, "Now take out your little eyes, Granny." These analogies are farfetched, but the important point is that the child is generalizing from the old to figure out the new.

Knowledge would be in a sorry state, however, if this were all these children did. But what Chukovsky's record so tellingly reveals is that it is not all they do. The children are not just making analogies. They are noting when these analogies do not work. They are seeing that something could be other than the way it is, through the analogy they have attempted to make, but that has partly failed.

> "The sun sets in the sea. Why is there no vapor?" (p. 21) (Other things produce vapor in water. Why not the sun?)
>
> "Where does the smoke fly?" (p. 29) (Other things that fly go somewhere. Where does the smoke go?)
>
> "Do chickens go out without rubbers?" (p. 29) (Chickens look like they're in rubbers. We go out without rubbers. The chickens are out, but always in rubbers.)

In each of these examples the children are thinking about what observed things are not. They are comparing them with things that are like them in some respects and unlike them in others, and are wondering about what they have not observed in the present instance. On other occasions children go so far as to directly examine the consequences of what does not obtain:

> "Mommies give birth to boys too? Then what are fathers for?" (p. 34) (Mommies give birth to girls and also boys. Fathers are like mommies (on whatever grounds). If mommies produce all children, then what are fathers for?)
>
> "Mommy, who gave birth to me? You? I knew it! If Daddy had given birth to me, I'd have a mustache." (p. 34) (Mommy gave birth to me and I look like Mommy. If Daddy gave birth to me, I'd look like Daddy. Daddy didn't give birth to me, so I don't look like him.)

Finally, children may deny something they know to be true, or that someone else claims is true, and then examine the consequences of the denial:

> "The rooster, could he completely, completely, completely forget that he is a rooster and lay an egg?" (p. 34) (To lay an egg you couldn't be a rooster. If the rooster [thought he] weren't a rooster, could he lay eggs (viz., not not lay eggs)?)

> Mother: "Don't you hear? The roll begs you to eat it." Child: "The roll can't talk. It doesn't have a mouth." (p. 28) (Things talk if they have mouths. The roll has no mouth. How can it talk?)
>
> Mother: "I'm gonna get you." Child: "You can't. My hands caught." (from Sugarman, 1983, Ch. 13) (To get me you need my hands. You can't get my hands, so you can't get me.)
>
> A 3 year-old has heard that a large cloud traversed the sky: "How can a cloud walk when it has no legs?" (Chukovsky, p. 104) (To walk means one has legs. If a thing does not have legs, then how can it be walking?)

In this last example, especially, we see the child reasoning from one thing that something is not to something else about it. She does this by reference to something else that has the property in question. Prompted by the use of (the Russian equivalent of) 'traverse' in reference to the cloud, the child thinks of other things that walk, observes that these have legs, observes that the cloud does not have legs, and concludes that it cannot walk. The logic is impeccable. But the reality is that things can 'walk' if they have no legs. What better a way to discover the richness of language, the tricks it can play -- the way it maps onto reality -- than as the child has done here?

On a more solemn note, the process we see unfolding in these examples is one that some investigators seem to have invoked in their accounts of children's construction of a grammar. Along these lines, Maratsos and Chalkley (1980) divide later grammatical acquisition into two phases. Initially, children could develop a productive grammatical system by an on-the-spot process of analogizing between individual lexical entires: they would form the past tense of one word, for example, by seeing how the past is formed with another word that they treat the same way as the first in other contexts (e.g., in forming the progressive). This 'unchecked' analogizing from one expression to another would account for the long

period of overgeneralization of regular forms that precedes the (stable) learning of exceptions. But later on children must learn these exceptions. They must learn when not to apply a rule or not to look for an analogously treated form to express some function, namely, when the term in question has a competing form to express that function.

Notice how this account dovetails with our manipulative search data. Initially children establish where the stickers are by looking for things that are like the objects that have stickers. Then they seem to recognize the relevance of negative instances -- in this case, dissimilar objects -- to their search.

All these observations suggest that by the middle preschool years, children begin to consider what things are not in the process of trying to figure out what they are. Or, in determining to what instances a given procedure, attribute, outcome, etc. applies, they consider other instances to which that procedure, etc. does and does not apply. This is a noteworthy development, in addition to the reasons we have already given, because the environment does not usually present tasks in the form 'determine not-x'. It presents them in the form 'determine x': find x, figure out what x is or is associated with. One has to think to look where x is not, to consider what it is not, or is not associated with.[1]

This is a preoccupation of preschoolers that as astute an observer as Piaget (1962) seems to have overlooked. He dwelled instead, for his own reasons, on the highly "assimilative" and particularistic nature of young children's analogizing. We have seen, though, that in drawing the analogies they do, children start to see where these analogies don't work. They may then, as Chukovsky's examples suggest, draw conclusions or raise questions about the thing for which they drew the analogy in the first place.

This is a sensible way for knowledge to develop. One could start anywhere, including with the "fantastic deductions" (Chukovsky, 1968, p. 20) that children make by virtue of their "priceless urge to establish... connections between separate facts" (p. 20). As long as they constantly balance what something is like against what it is not like, they may eventually get to the truth, or at least to the conventional wisdom.

Footnote

1 One may note that prohibitions take the form, "You may not do x", or perhaps, "You may not do x, but you may do y." Whatever from injunctions take (and this, as evidence of what adults think children understand, might provide some clues as to what they do understand), we would argue that children would not begin to use their concept of what they may not do to delimit what they may do (or vice versa) until around 3 -- or, more positively, they might do this as early as 3.

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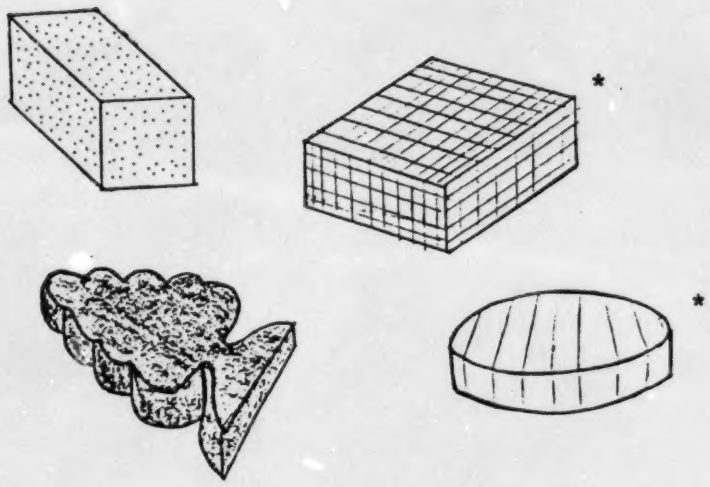
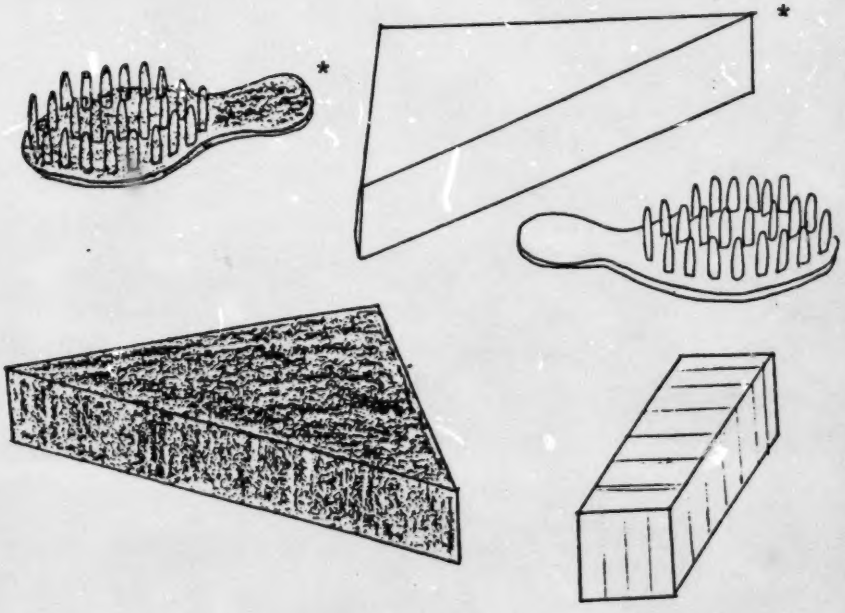
FIGURE 1. TASK STIMULI



Nonoverlapping Task

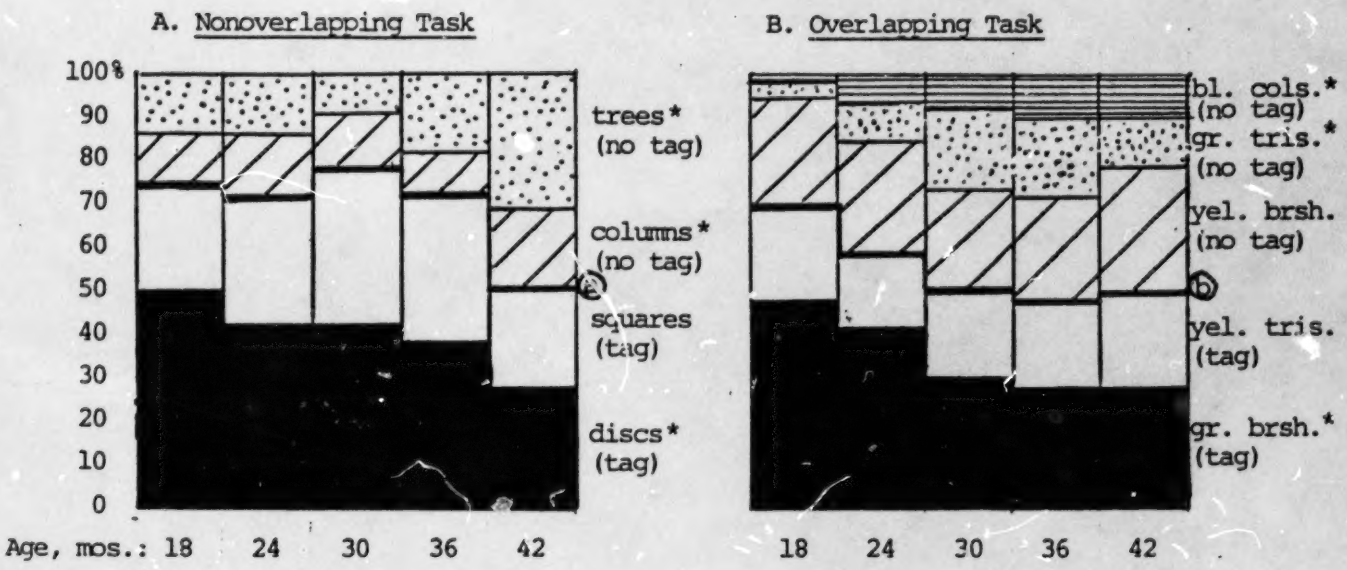


* Every item in designated class has a sticker attached underneath.

NOTE: Each class is represented by four exemplars.

Overlapping Task

FIGURE 2. MEAN PER CENT OF SELECTIONS FROM EACH CLASS



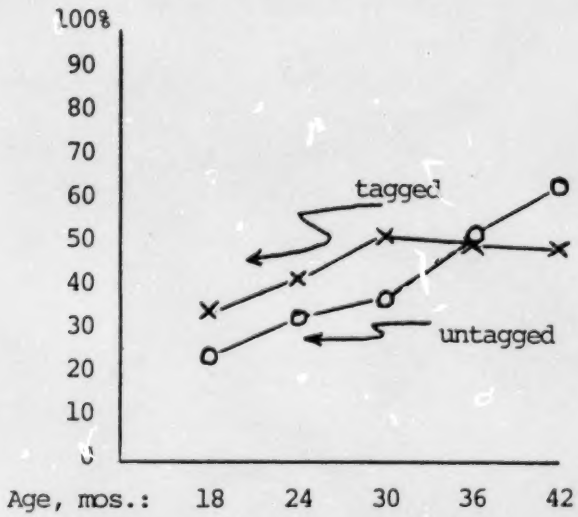
*The increase or decrease in use of these classes was significant ($p < .05$) by a linear trend F test. Note, trends within the same graph are not independent.

ⓐ Linear trend on age for % of selections involving tagged, as opposed to untagged, objects:
F (1,35) = 8.01, $p < .008$

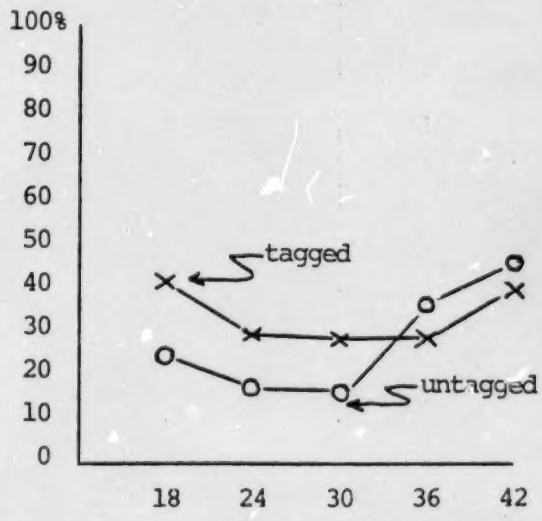
ⓑ Linear trend on age for % of selections involving tagged, as opposed to untagged, objects:
F (1,35) = 8.63, $p < .006$

FIGURE 3. PER CENT OF TARGET VS. NONTARGET SELECTIONS FOLLOWED BY SELECTION OF AN IDENTICAL OBJECT

A. Nonoverlapping Task



B. Overlapping Task



Linear trend on age X % of tagged vs. untagged selections followed by identical object:
F (1,35) = 4.75, $p < .04$

F (1,35) = 4.10, $p < .051$

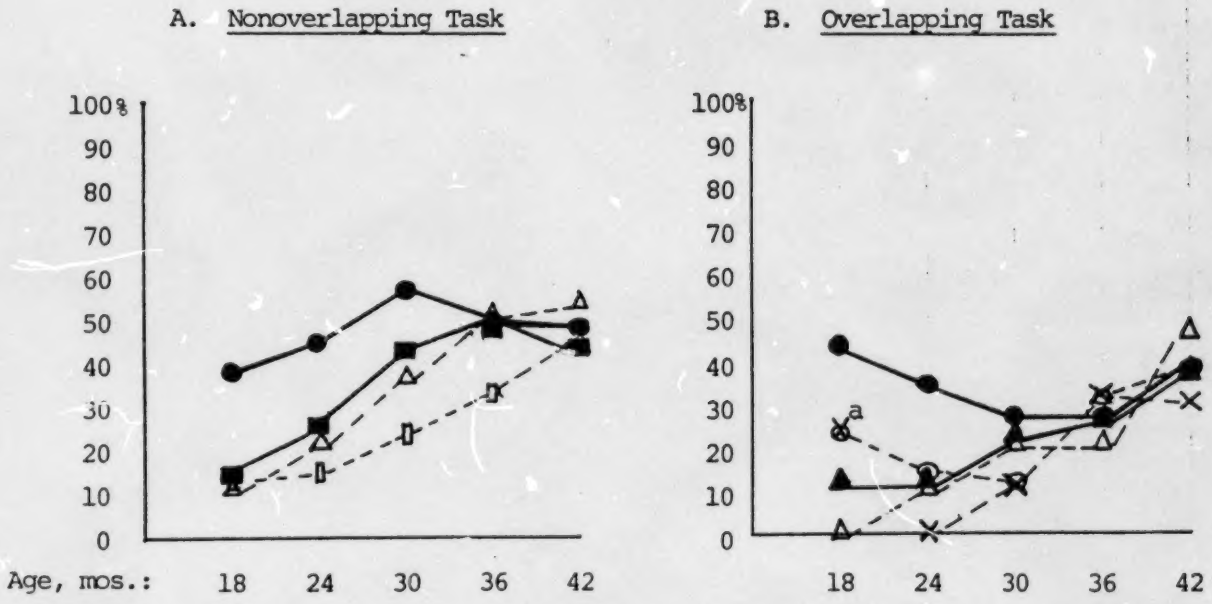
Linear trend on age for % of tagged selections followed by identical object:
F (1,35) = 4.71, $p < .04$

F (1,35) = .006, $p > .9$

Linear trend on age for % of untagged selections followed by identical object:
F (1,35) = 9.98, $p < .004$

F (1,35) = 7.82, $p < .009$

FIGURE 4. PER CENT OF EACH CLASS SELECTION FOLLOWED BY SELECTION OF AN IDENTICAL OBJECT



DARK ITEMS = TAGGED

LIGHT ITEMS = UNTAGGED

- ● discs: linear trend on age for % followed by identical object, $p > .2$
- ■ squares: $p < .001$
- ▯ columns: $p < .03$
- △ trees: $p < .003$

Linear trend on age X % of discs vs. squares (tagged objects) followed by identical object:
$F(1,35) = 4.34$, $p < .05$

- ● gr. brsh.: linear trend on age for % followed by identical object, $p > .4$
- ▲ yel. tri.: $p < .02$
- ○ yel. brsh.: $p > .08$
- △ gr. tri.: $p < .003$
- × bl. col.: $p > .3$

[a] only two 18-month-olds selected blue columns and thus contribute to this score.

Linear trend on age X % of gr. brshes vs. yel. tris. (tagged objects) followed by identical object:

$F(1,35) = 6.06$, $p < .02$